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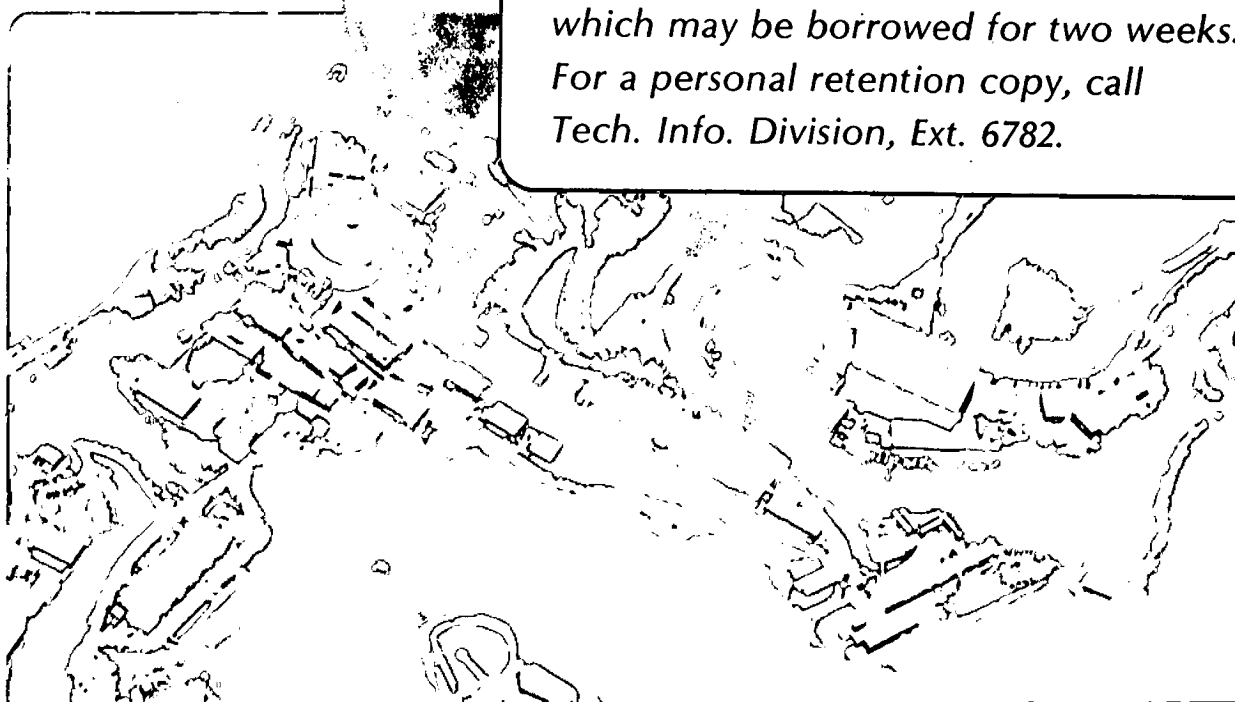
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EFFECTS ON SELF QUENCHING STREAMER BEHAVIOR

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**Gas Composition, Pressure, and Chamber Geometry  
Effects on Self Quenching Streamer Behavior\***

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"Self quenching streamer" behavior produces large, saturated, fast pulses in thick anode wire chambers filled with a variety of heavily quenching gas mixtures. A comparison of the performance of these mixtures and a study of the effects of gas pressure and chamber geometry are presented.

## 1. Introduction

The observation of anomalously large pulses produced on thick anode wires in wire chambers filled with heavily quenching gas mixtures was first reported in the early work with multiwire proportional chambers.<sup>(1)</sup> This mode of operation was originally referred to as "limited Geiger" and was thought to be due to discharges which propagated some limited ( $\approx 10$  mm) distance along the wire. Since this postulated mechanism should result in a large product of dead time and length of dead zone along the wire, most investigators treated these pulses as a nuisance phenomenon to be avoided. More recently it has been observed<sup>(2)</sup> that this dead time, dead length product is much smaller than expected. Optical investigations<sup>(3,4)</sup> have revealed that the production mechanism involves narrow ( $150\text{--}200\text{ }\mu\text{m}$ ) streamers which propagate orthogonally away from the anode. These streamers propagate outwards for several millimeters and then quench themselves. The mode of operation is now referred to as "self-quenching streamer" (SQS) behavior.

The signals produced in the SQS mode are large ( $\approx 50$  mV into  $50\text{ }\Omega$ ), have fast rise times ( $\approx 10$  nsec), short durations ( $\approx 100$  nsec) and are not followed by the long dead times typical of the Geiger-Muller mode of operation. The signals are saturated in the sense that the pulse size is independent of the amount of initial charge deposited by the ionizing radiation but does continue to increase with operating voltage.

In this report we present a comparison of SQS performance for various gas mixtures and pressures in various chamber geometries. These results should provide guidance in the design of the detectors employing the SQS mode of operation.

## 2. Test chambers

Two test chambers were used to make the measurements described below. One was a prototype for a large, coarse resolution hodoscope and consisted of 2 cm spaced anode wires, sandwiched between cathode foils with a 2 cm cathode-anode gap. The second chamber was of a design which allowed convenient variation of the anode wire

spacing and of the cathode-anode gap. This chamber was equipped for cathode readout and was capable of being pressurized to twice atmospheric pressure.

### 3. Gas Mixtures

SQS behavior was first observed in "magic gas"<sup>(1)</sup> and then in mixtures of argon with large amounts of hydrocarbons<sup>(2-4)</sup> and finally in argon-carbon dioxide mixtures.<sup>(5)</sup> We have observed SQS behavior in a large variety of Noble gas-complex molecule quencher mixtures. A comparison of five such gas mixtures is presented in Table 1 where we have listed, for a voltage approximately halfway between the onset of streamer behavior and the onset of continuous discharge, the average pulse height (into 50  $\Omega$ ) produced by the  $\beta$ -spectrum of  $^{90}\text{Sr}$ , and as a measure of the degree of "saturation" (independence of the amount of initial charge deposited), the fractional width ( $\Delta V/V$ ) of that pulse height distribution. All of the gas mixtures consisted of 50% Noble gas and 50% quencher. The measurements were made in the first test chamber strung with 75  $\mu\text{m}$  diameter anode wires.

The shape of the pulses is strongly affected by the proportions of the gas mixture. Pulses generated in five different concentrations of carbon dioxide in argon are shown in Fig. 1. At the lowest concentration, 10%  $\text{CO}_2$ , the pulse shape is reminiscent of the Geiger-Muller mode of operation with slow ( $\approx 75$  nsec) rise times and long ( $\approx 1$   $\mu\text{sec}$ ) pulse durations. The rise times become faster and the pulse duration shortens as the  $\text{CO}_2$  concentration is increased. At a concentration of 50%  $\text{CO}_2$ , the rise time has shortened to approximately 6 nsec and the duration of the pulse has been reduced to approximately 80 nsec. Further increase in the  $\text{CO}_2$  concentration results in the rise times remaining about the same but the pulse length's continuing to shorten, reaching a length of approximately 35 nsec for a 90% concentration of  $\text{CO}_2$ . SQS behavior is not seen in pure  $\text{CO}_2$ .

#### 4. Geometry and pressure

The effect of anode wire diameter was studied at atmospheric pressure using the first test chamber and at twice atmospheric pressure using the second chamber.

At atmospheric pressure, when wire diameters of  $50\text{ }\mu\text{m}$  and smaller were employed, the discontinuous transition from proportional to SQS modes of operating was not seen. A narrow region of saturated behavior was seen just before the onset of continuous discharge. This region is referred to as the "saturated avalanche region" by other authors.<sup>(6)</sup> When anodes of  $75\text{ }\mu\text{m}$  and greater diameter were employed, the discontinuous transition was observed. The pulse height as a function of voltage is shown in Fig. 2 for  $25\text{ }\mu\text{m}$  and  $75\text{ }\mu\text{m}$  diameter anodes. The operating voltage where the transition occurred increased by approximately 500 volts as the wire diameter was increased from  $75\text{ }\mu\text{m}$  to  $125\text{ }\mu\text{m}$ . When anodes larger than  $125\text{ }\mu\text{m}$  were employed, no signals were seen before the onset of continuous discharge.

At twice atmospheric pressure, SQS behavior was seen with anode diameters as small as  $20\text{ }\mu\text{m}$ .

Amplification in the proportional mode occurs very close (a few wire diameters) to the anode while SQS amplification occurs in the weaker fields further from the anode. This is illustrated in the photographs of proportional and streamer discharges in references 4 and 5. One might expect distortion of the far fields, by either too closely spaced anode wires or by too narrow an anode-cathode gap, to interfere with the SQS mechanism.

When a typical MWPC arrangement (2 mm anode spacing, 5 mm anode-cathode gap) of  $75\text{ }\mu\text{m}$  wires was used in the second test chamber, SQS behavior did not occur at any attainable voltage. Proportional mode pulses, of very small amplitude due to the thick anode wires, were seen. Increasing the anode cathode gap to 10 and then to 15 mm failed to produce SQS pulses, as did increasing the chamber pressure to two atmospheres. However, when the anode spacing was increased to 4mm, streamer

pulses were seen, at both atmospheric and twice atmospheric pressure, with anode-cathode gaps as small as 5 mm.

## 5. Cathode response

The second test chamber was instrumented for cathode readout via electromagnetic delay lines.<sup>(7)</sup>

When the radiation being detected in a wire chamber consists of photons which deposit their energy at one point in the chamber rather than all along the track through the anode-cathode gap, as is the case for charged particles, an asymmetry in the induced pulses registered on the two cathodes is seen. This asymmetry should be more pronounced in the SQS mode than in the proportional mode if long streamers are indeed being propagated outward from the wire. Fig. 3 shows the cathode response to irradiating the chamber with 59 keV x rays from  $^{55}\text{Fe}$  and with  $\beta^-$  particles from  $^{90}\text{Sr}$ . To dramatize any asymmetries, the signal from the cathode further from the source of the ionizing radiation was inverted before being displayed.

A clear asymmetry in cathode response is seen in the case of irradiation with the  $^{55}\text{Fe}$  source. This asymmetry is consistent with the number of photons expected to convert in each of the two anode-cathode gaps. When the  $^{90}\text{Sr}$  source is used, the number of avalanches initiated in the two gaps is expected to be the same. This expectation is confirmed by the symmetry in response seen in Fig. 3b.

The asymmetry in cathode response gives further confirmation to the model of SQS behavior in which streamers propagate outward from the wire rather than along it. Due to this asymmetry some care should be taken in the design of readout electronics for the cathodes of photon detecting chambers. The asymmetry can actually be exploited. For example, the difference in response between the two cathodes can give information on the depth of the interaction in the chamber. This information can be used to reduce the parallax error in such photon detecting applications as positron emission tomography.<sup>(8)</sup>

## 6. Conclusion

Self quenching streamers may be produced in a large variety of Noble gas-complex molecule quencher mixtures. Varying the proportions of the gas mixture allows some degree of tailoring of the pulse shape. Some care must be exercised in the choice of anode wire spacing if successful SQS operation is to be achieved. Care must also be exercised if cathode readout is used due to large response asymmetries occurring when photons are detected.



## References

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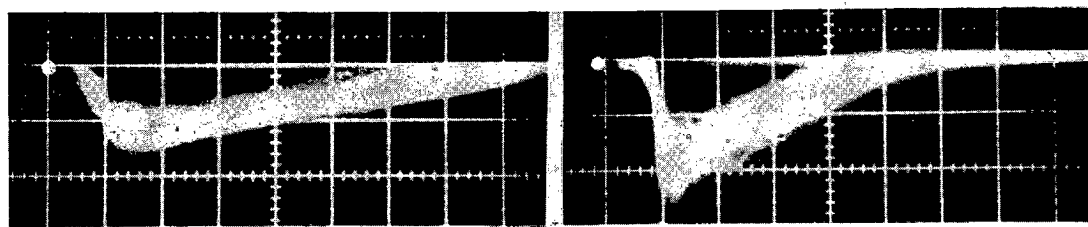
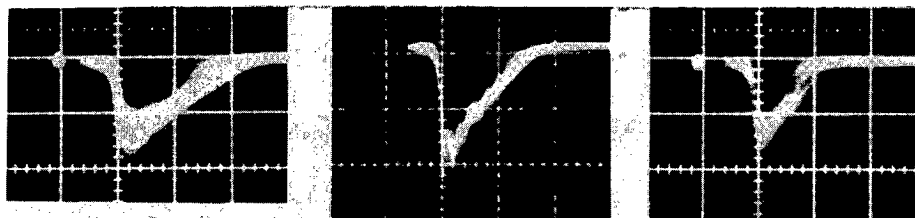
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Table 1

Gas Mixture	Operating Voltage	Average Pulse Height	$\Delta V/V$
Ar-CO <sub>2</sub>	5000 V.	42 mV	0.14
Ar-C <sub>2</sub> H <sub>6</sub>	4600 V.	43 mV	0.30
Ar-CH <sub>4</sub>	4600 V.	84 mV	0.19
Ne(10% He)-C O <sub>2</sub>	5500 V.	44 mV	0.21
Ar-CF <sub>4</sub>	5000 V.	47 mV	0.15

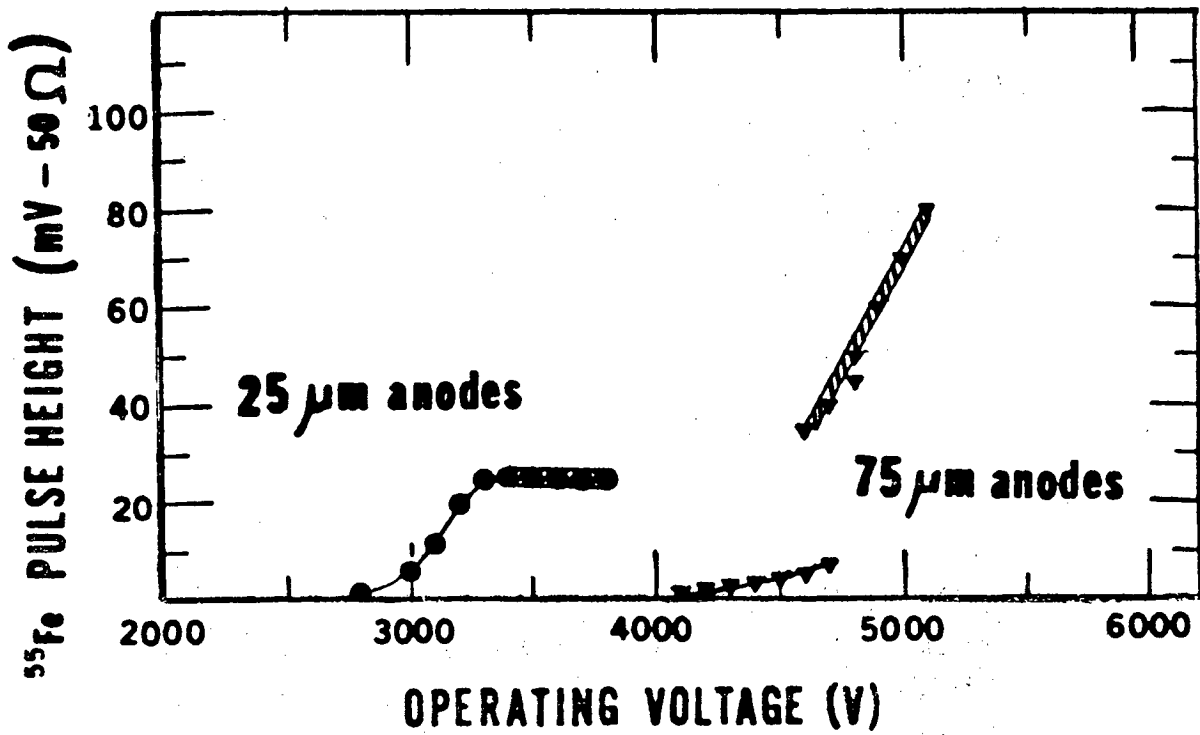
**Figure Captions**

- (1) Effect of carbon dioxide concentration on pulse shape (a) 10%, (b) 33%, (c) 50%, (d) 66%, (e) 90%, balance argon. Operating voltages were chosen to give comparable pulse heights. 20 mV/div. into 50  $\Omega$ , 50 nsec/div.
- (2) Pulse height as a function of operating voltage for 25  $\mu\text{m}$  and 75  $\mu\text{m}$  anode diameters.
- (3) Cathode responses when chamber is irradiated with (a)  $^{55}\text{Fe}$ , (b)  $^{90}\text{Sr}$ . Top trace is cathode nearer source, bottom trace has been inverted. 50 mV/div. into 10 k $\Omega$ , 50 nsec/div.

**a****b****c****d****e**

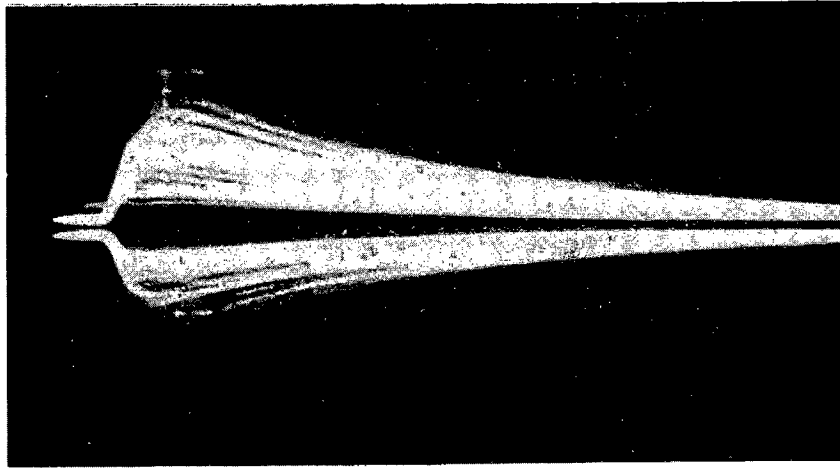
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Fig. 1



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Fig. 2

**a****b**

XBB 820-8784

Fig. 3

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